Virtual museums, a survey and some issues for consideration

4 authors, including:

Stella Sylaiou
Hellenic Open University
70 PUBLICATIONS   **516** CITATIONS

SEE PROFILE

Fotis Liarokapis
Masaryk University
123 PUBLICATIONS   **1,811** CITATIONS

SEE PROFILE

Kostas Kotsakis
Aristotle University of Thessaloniki
53 PUBLICATIONS   **1,398** CITATIONS

SEE PROFILE

Some of the authors of this publication are also working on these related projects:

Virtual Multimodal Museum (ViMM) View project

Image Database Montelius for Neolithization View project

Review

Virtual museums, a survey and some issues for consideration

Sylaiou Styliani [a],*, Liarokapis Fotis [b], Kotsakis Kostas [a,c], Patias Petros [a,d]

[a] *Inter-departmental Postgraduate Program of School of Technology 'Protection, Conservation and Restoration of Cultural Monuments',
Aristotle University of Thessaloniki, Thessaloniki 54124, Greece*
[b] *Interactive Worlds Applied Research Group, Coventry University, Coventry, CV1 5FB, United Kingdom*
[c] *Department of History and Archaeology, Aristotle University of Thessaloniki, Thessaloniki, Greece*
[d] *Department of Rural & Surveying Engineering, Aristotle University of Thessaloniki, Thessaloniki, Greece*

Abstract

Museums are interested in the digitizing of their collections not only for the sake of preserving the cultural heritage, but to also make the information content accessible to the wider public in a manner that is attractive. Emerging technologies, such as VR, AR and Web3D are widely used to create virtual museum exhibitions both in a museum environment through informative kiosks and on the World Wide Web. This paper surveys the field, and while it explores the various kinds of virtual museums in existence, it discusses the advantages and limitation involved with a presentation of old and new methods and of the tools used for their creation.
© 2009 Elsevier Masson SAS. All rights reserved.

Keywords: Virtual museums; E-Heritage; Cultural informatics; Virtual reality; Augmented reality; Haptics

1. Introduction

Silverstone states that 'museums are in many respects like other contemporary media. They entertain and inform; they tell stories and construct arguments; they aim to please and to educate; they define, consciously or unconsciously; effectively or ineffectively, an agenda; they translate the otherwise unfamiliar and inaccessible into the familiar and accessible' [1, p. 162]. An extensive research work [2,3] and a survey of the European museum sector [4] have shown that information technologies such as the World Wide Web (WWW) enhanced by three-dimensional visualization tools can provide valuable help to achieve the aims mentioned above. Furthermore, their use by a wide range of cultural institutions, such as museums, has become easier due to an ever-increasing development of interactive techniques and of new information technology software and hardware, accompanied by a decrease in cost. Information technologies provide solutions to issues of space limitation, of the considerable exhibitions cost and of curator's concerns concerning the fragility of some museum artefacts. Conferences such as the ICHIM Conferences on Hypermedia and Interactivity in Museums[1] started in 1991 and Museums and the Web,[2] established in 1997, highlight the importance of introducing new technologies in museums. The utility and the potential benefits for museums of emerging technologies such as Virtual Reality (VR) [5–7], Augmented Reality (AR) [8–10] and Web technologies [11,12] have been well documented by a number of researchers [13].

In the 1980s, museums influenced by the New Museology and began to change the way they conveyed the context information of the exhibits to the wider public. There was a shift in the museology concept towards considering that the context of a cultural artefact was more important than the item itself [14–17]. By means of innovative methods and tools and by taking advantage of the WWW potential as an information source, virtual museums were created. They have made the content and context of museum collections more accessible and attractive to the wide public and have enriched the museum experience. There is no official figure yet for the number of virtual museums presently existing worldwide but we know that there are thou-

---

* Corresponding author. Tel.: +30 2310 996407; fax: +30 2310 994207.
E-mail address: sylaiou@photo.topo.auth.gr (S. Styliani).

[1] Available at: http://www.archimuse.com/conferences/ichim.html.
[2] Available at: http://www.archimuse.com/conferences/mw.html.

sands of them and that their number is rapidly on the increase [18]. This article will present the results of a survey on the current state-of-the-art in virtual museums. The purpose behind this is threefold:

(a) to review the various types and forms that a virtual museum can have and the characteristics of these;
(b) to present an analysis of their advantages and to highlight their potential;
(c) to present an overview of emerging technologies used by virtual museums.

2. Types of virtual museums

The idea of the virtual museum was first introduced by André Malraux in 1947. He put forward the concept of an imaginary museum (*le musée imaginaire*) [19], a museum without walls, location or spatial boundaries, like a virtual museum, with its content and information surrounding the objects, might be made accessible across the planet. A virtual museum is:

"*a collection of digitally recorded images, sound files, text documents and other data of historical, scientific, or cultural interest that are accessed through electronic media*" [20].

With no standard definition prevailing for the term 'virtual museum', the definition adopted for the purpose of this article describes it as:

"*(. . .) a logically related collection of digital objects composed in a variety of media, and, because of its capacity to provide connectedness and various points of access, it lends itself to transcending traditional methods of communicating and interacting with the visitors being flexible toward their needs and interests; it has no real place or space, its objects and the related information can be disseminated all over the world*" [21].

Another less rigid definition states that a virtual museum can be a digital collection that is presented either over the Web, or to an intranet, either via a personal computer (PC), an informative kiosk, a personal digital assistant (PDA), or even to a CD-ROM as an extension of a physical museum, or that it can be completely imaginary. Furthermore, the abstract term virtual museum can take various forms depending on the application scenario and end-user. It can be a 3D reconstruction of the physical museum [22]. Alternatively, it can be a completely imaginary environment, in the form of various rooms, in which the cultural artifacts are placed [23].

According to ICOM [24], there are three categories of virtual museums on the Internet that are developed as extensions of physical museums: the brochure museum, the content museum and the learning museum. The brochure museum aims at informing future visitors about the museum and is mainly used as a marketing tool, with basic information such as location, opening hours and sometimes a calendar of events etc. [25,26], in order to create motivation to visit the walled museum. The content museum is a website created with the purpose of making information about the museum collections available. It can

be identified to a database containing detailed information about the museum collections, with the content presented in an object-oriented way. The learning museum is a website, which offers different points of access to its virtual visitors, depending on their age, background and knowledge. The information is presented in a context-oriented, rather than object-oriented way. Moreover, the site is educationally enhanced and linked to additional information intended to motivate the virtual visitor to learn more about a subject of particular interest to them and to visit the site again. The goal of the learning museum is to make the virtual visitor come back and to make him/her establish a personal relationship with the online collection.

3. Emerging tools and technologies used by virtual museums

Technological advances that have emerged as areas of crucial interest are making it possible to use sophisticated tools to provide customized interfaces for the generation of virtual museums, to design a virtual museum exhibition in a number of ways [27,58] and to get used as conveyors of information for knowledge construction, acquisition and integration. New types of interfaces, interaction techniques and tracking devices are developing at a rapid pace and can be integrated into multimodal interactive VR and AR interfaces [9]. The first studies in the field were mainly focused on static presentations of texts and photos concerning a museum. Later on, the exhibits tended to be more dynamic and interactive rather than static in nature and authoritative [28,27], thus creating an approach which was closer to reality and enhancing the experience for virtual visitors. Usually, the structure of most virtual exhibitions is defined by the structure of exhibition spaces [11] that consist of two types of elements: the Virtual Galleries and the Cultural Objects. Exhibits are the principal means through which museums communicate their mission objectives and they can be static or interactive. According to research the key features of an online interactive exhibit are:

(a) multiplicity of contexts for the user to connect with the exhibit in a seamless manner;
(b) good instructional design;
(c) pro-active learning contexts;
(d) good balance between learning and leisure;
(e) no text-heavy pages to interfere with the learning experience [29].

In this section, a brief overview of the most characteristic methods and tools currently used for the generation of virtual museum exhibitions and their exhibits are presented.

3.1. Imaging technology

Virtual museums need high-resolution images in order to provide as much information as possible about the virtual exhibits. However, the level-of-detail (LOD) is dependent on the resolution of the digital images and high-resolution conventional images produce very large files that are difficult to manage and

to transmit across networks because of their dependence on bandwidth availability (slow Internet connections). A strategy adopted to confront this problem is the image servers that use a "Russian doll" imaging architecture and give the user scalability and interactivity opportunities, because multiple resolutions of an image are stored in a single file and make it possible to progressively transmit an image. FlashPix and then JPEG2000 are the two image formats that introduced a new concept for imaging architecture [30]. Metadata storing is also allowed. This image format is used by various museums such [31–34]. Some of the FlashPix features are adopted by the JPEG2000 image format that also has the potential of progressive image transmission and scalability and some new features that fill the gaps for the inclusion of metadata and the protection of the content [35] of earlier standards for encoding digital media. The advantages of the image format have been extensively investigated in research work [36,37] and the JPEG2000 format has been adopted by cultural institutions [38–40].

3.2. Web3D exhibitions

Internet technologies have the tremendous potential of offering virtual visitors ubiquitous access via the WWW to a virtual museum environment. Additionally, the increased efficiency of Internet connections (i.e. ADSL) makes it possible to transmit significant media files relating to the artefacts of virtual museum exhibitions. The most popular technology for the WWW visualisation includes Web3D which offers tools such as VRML and X3D, which can be used for the creation of an interactive virtual museum. The Web3D consortium [41] contains open standards for real-time 3D communication and the most important standards include: VRML97 and X3D and are presented below. Many museum applications based on VRML have been developed for the web [12,42]. As from 4 April 1997, VRML97 has stood for Virtual Reality Modeling Language. Technically speaking, VRML is neither VR, nor a modelling language, but a 3D interchange format which defines most of the commonly used semantics found in today's 3D applications such as hierarchical transformations, light sources, viewpoints, geometry, animation, fog, material properties, and texture mapping. Another definition states that VRML serves as a simple, multi-platform language for publishing 3D Web pages as well as for providing the necessary technology to integrate three dimensions, two dimensions, text, and multimedia into a coherent model. "When these media types are combined with scripting languages and Internet capabilities, an entirely new genre of interactive applications is possible" [43]. This is due to the fact that some information is best experienced in three-dimensional form, such as the information of virtual museums [11,9]. However, VRML can be excessively labour-intensive, time consuming and expensive. QuickTime VR (QTVR) and panoramas that allow animation and provide dynamic and continuous 360° views might represent an alternative solution for museums such as in [44]. As with VRML, the image allows panning and high-quality zooming. Furthermore, hotspots that connect the QTVR and panoramas with other files can be added [45]. In contrast, X3D is an Open Standards XML-enabled 3D file format offering real-time communication of 3D data across all applications and network applications. Although, X3D is sometimes considered as an Application Programming Interface (API) or a file format for geometry interchange, its main characteristic is that it combines both geometry and runtime behavioral descriptions into a single file alone. Moreover, X3D is considered to be the next revision of the VRML97 ISO specification, incorporating the latest advances in commercial graphics hardware features, as well as improvements based on years of feedback from the VRML97 development community. For a virtual museum, making possible the presentation of virtual exhibitions, the visualization usually consists of dynamic Web pages embedded with 3D VRML models [9]. This can be enhanced with other multimedia information (i.e. movie clips, sound) and used remotely over web protocols (i.e. HTTP). A more 3D graphics format, is COLLAborative Design Activity (COLLADA) [46] which defines an open standard XML schema for exchanging digital assets among various graphics software applications that might otherwise store their assets in incompatible formats. One of the main advantages of COLLADA is that is includes more advanced physics functionality such as collision detection and friction (which Web3D does not support).

Moreover, more powerful technologies that have been used in museum environments include OpenSceneGraph (OSG) [47] and a variety of 3D game engines [48,49]. OSG is an open source multi-platform high performance 3D graphics toolkit, used by museums [50,51] to generate more powerful VR applications, especially in terms of immersion and interactivity since it supports text, video, audio and 3D scenes into a single 3D environment. On the other hand, 3D games engines are also very powerful and they provide superior visualization and physics support. Serious games is a new concept and allows for collaborative use of 3D spaces which are used for learning and educational purposes in a number of educational domains. The main strengths of serious gaming applications could be generalised as being in the areas of communication, visual expression of information, collaboration mechanisms, interactivity and entertainment. Both technologies (OSG and 3D game engines) compared to VRML and X3D can provide very realistic and immersive museum environments but they have two main drawbacks. First, they require advanced programming skills in order to design and implement custom applications. Secondly, they do not have support for mobile devices such as PDAs and 3G phones.

3.3. Virtual reality exhibitions

VR is a simulation of a real or imaginary environment generated in 3D by digital technologies that is experienced visually and provides the illusion of reality. Over the past few years, modeling software has become affordable and the cost of building virtual environments has fallen considerably, thus fuelling new application domains such as virtual heritage. For example, low cost and highly interactive VR experiences for museum visitors can be created on the basis of standard hardware components (a relatively low cost PC with cheap graphics accelerator, a touch screen and a sensor device, e.g. a inertia cube), some applica-

tion software and suitable browser plug-ins. VR applications can be used by distributed groups of large numbers of players, and are immersive and interactive. In a VR environment participants get immersed into a completely artificial world but there are various types of VR systems, which provide different levels of immersion and interaction. Heim believes that weak VR can be characterized by the appearance of a 3D environment on a 2D screen [52].

In contrast, strong VR is the total sensory immersion, which includes immersion displays, tracking and sensing technologies. Common visualization displays include head-mounted displays and 3D polarizing stereoscopic glasses while inertia and magnetic trackers are the most popular positional and orientation devices. As far as sensing is considered, 3D mouse and gloves can be used to create a feeling of control of an actual space. An example of a high immersion VR environment is Kivotos, a VR environment that uses the CAVE® system, in a room of 3 meters by 3 meters, where the walls and the floor act as projection screens and in which visitors take off on a journey thanks to stereoscopic 3D glasses [53]. As mentioned earlier, virtual exhibitions can be visualized in the Web browser in the form of 3D galleries, but they can also be used as a stand-alone interface (i.e. not within the web browser). In addition, a number of commercial VR software tools and libraries exist, such as Cortona [54], which can be used to generate fast and effectively virtual museum environments. However, the cost of creating and storing the content (i.e. 3D galleries) is considerably high for the medium and small sized museums that represent the majority of cultural heritage institutions. An overview of the tools and methods available to visitors visualizing a virtual museum has been already carried out [55].

3.4. Augmented reality exhibitions

In addition to the VR exhibitions, museum visitors can enjoy an enhanced experience by visualizing, interacting and navigating into museum collections (i.e. artifacts), or even by creating museum galleries in an AR environment. The virtual visitors can position virtual artifacts anywhere in the real environment by using either sophisticated software methods (i.e. computer vision techniques) or specialized tracking devices (i.e. InertiaCube). Although the AR exhibition is harder to achieve, it offers more advantages to museum visitors as compared to Web3D and VR exhibitions. Specifically, in an AR museum exhibition, virtual information (usually 3D objects but it can also be any type of multimedia information, such as textual or pictorial information) is overplayed upon video frames captured by a camera, giving users an impression that the virtual cultural artifacts actually exist in the real environment. Through human–computer interaction techniques users can examine thoroughly the virtual artifacts through tactile manipulation of fiducials (i.e. markers) or sensor devices (i.e. pinch-gloves). This 'augmentation' of the real-world environment can lead to an intuitive access to the museum information and enhance the impact of the museum exhibition on virtual visitors.

One of the earliest examples of an interactive virtual exhibition is an automated tour guide system that uses AR techniques [56]. It can superimpose meaningful audio on the real world on the basis of the location of the user, offering the advantage of enriching visitors' experiences. Also, the Meta-Museum guide system [57] is based on AR and artificial intelligence technologies and provides a communication environment between the real world and cyberspace to maximize the utilization of a museum's archives and knowledge base. Furthermore, AR has been experimentally applied to make it possible to visualise incomplete or broken real objects as they were in their original state by superimposition of the missing parts [10]. Finally, the ARCO system [23,11] provides customised tools for virtual museum environments, ranging from the digitisation of museum collections to the tangible visualization of both museum galleries and artifacts. ARCO developed tangible interfaces that allow museum visitors to visualise virtual museums in Web3D, VR and AR environments sequentially. A major benefit of an AR-based interface resides in the fact that carefully designed applications can themselves provide novel and intuitive interaction without the need for expensive input devices.

3.5. Mixed reality exhibitions

Finally, mixed reality (MR) relies on a combination of VR, AR and the real environment. According to Milgram and Kishino's virtuality-continuum, real world and virtual world, objects are presented together on a single display [58] with visual representation of real and virtual space [59]. An example of the use of MR techniques in a museum environment is the Situating Hybrid Assemblies in Public Environments (SHAPE) project [60] that uses hybrid reality technology to enhance users' social experience and learning in museum and other exhibition environments, with regard to cultural artifacts and to their related contexts. It proposes the use of a sophisticated device called the periscope (it is now called the Augurscope), which is a portable mixed reality interface, inside museum environments to support visitors interaction and visualisation of artifacts.

3.6. Haptics

'Haptics, from the Greek word 'haptein', involves the modality of touch and the sensation of shape and texture which an observer feels when exploring a virtual object' [61]. Haptics makes it possible to achieve the extension of visual displays to render them more realistic, useful and engaging for visitors. One of the most characteristic museum applications using haptics is at the University of Southern California's Interactive Art Museum [62]. In this case, the PHANToM device was used within a museum allowing visitors to touch and feel virtual artifacts [63] PHANToM is a desk-grounded robot that allows simulation of single fingertip contact with virtual objects through a pointing device (i.e. stylus). In addition, its actuators communicate forces back to the user's fingertips as it detects collisions with virtual objects, simulating the sense of touch. Another application is the 'Museum of Pure Form' a VR system where users can interact, through the senses of touch and sight, with digital models of 3D art forms and sculptures. Its aim was to change the way normal users perceive sculptures, statues or,

more generally, any type of 3D artwork [64]. Two different presentations of this application were developed including a system placed inside several museums and art galleries around Europe as well as a system placed inside a CAVE^{TM} environment [27].

3.7. Use of handheld devices in museums

Handheld devices represent a wide range, including cell phones, personal-digital assistants (PDAs) and tabloids. Improvements during the past few years in optics, processing power and ergonomics have initiated a number of museum-based applications. A prototype application is the City co-visiting system which combines VR, hypermedia technology, handheld devices and ultrasound tracking technology to allow three visitors, one on-site and two remote [65]. A location–aware PDA is used for the on-site visitor to display the ongoing positions of all three visitors on a map of the gallery while the two off-site visitors use two different environments: a web-only environment and a VE. The application also supports web-based multimedia information for the off-site visitors that are dynamically presented upon movement across the map. The San Francisco Museum of Modern Art (SFMoMA) has also presented work from its permanent collection in iPAQ handhelds [66]. Furthermore, the giCentre at City University is exploring LBS through the use of mobile computing including the use of third-generation (3G) phones and PDAs [67]. Users can interact with the virtual artifacts using either the menu interface or the stylus. In addition, using external sensors (i.e. inertia cube, accelerometers and digital compass) museum visitors can perceive virtual information about the artifacts in relation to their location inside the museum.

4. Real and virtual museum

According to the definition of the International Council of Museums (ICOM) about museums [68]: "A museum is a non-profit making, permanent institution in the service of society and of its development, and open to the public, which acquires, conserves, researches, communicates and exhibits, for purposes of study, education and enjoyment, material evidence of people and their environment." Virtual museum enjoy the same functions of acquisition, storage, documentation, research, exhibition and communication as the 'brick and mortar' museums as set out by the above definition. They can, in addition, act in a complementary and auxiliary manner. A virtual museum website can provide worldwide publicity. Research has revealed that 70% of people visiting a museum website would subsequently be more likely to go and visit the 'real' museum [69]. Museum curators can digitally preserve the artifacts of their collections. The effective safeguarding of cultural artifacts can be achieved through the use of technological advances, by means of the comparison of different images across time to monitor their conservation. Furthermore, they provide the means to create digital representations of cultural artifacts and database technologies with which multimedia information about the virtual museum artifacts can be stored and retrieved whenever is needed. The digitized information can be re-used in a variety of

ways, for different purposes and probably even by other cultural institutions.

Additionally, virtual museums allow museum curators to experiment with various arrangements of 3D objects inside the gallery, to test different designs before deciding on the presentation style of a temporary exhibition. They create and disseminate to the wider public virtual models of cultural artifacts that combine archaeological accuracy and reliability with aesthetic pleasure. Finally, they visualize the digital representation of the cultural objects via VR and AR interfaces, so as to make available to the wider audience more realistic and appealing virtual museum exhibitions that can be interactively and easily explored. In addition to this, they can overcome limitations of space in respect of the number of objects accessible in the real museum [70].

The WWW is widely used by museums for putting their collections online [71], not only because it is very popular (especially among young people), but also because it is in the hands of museum curators a powerful communication tool that can deliver in a fast, user-friendly and low-cost information about the museum to potential virtual visitors and provides museum curators with a great variety of opportunities in terms of museum data dissemination. As it has been already mentioned, virtual museums, through innovative technologies, provide unrestricted round-the-clock access to their visitors through the WWW. Virtual museums can provide access from any place and to anyone, including people with special needs (visual, acoustic, speech and motor disabilities and learning difficulties). The UN Convention on the Rights of Persons with Disabilities [72], the Americans with Disabilities Act of 1990 (ADA) [73] and the Disability Discrimination Act (DDA) in the UK state that disabled people have equal rights of 'access to goods, facilities and services' [74]. It is therefore the responsibility of Cultural institutions, such as museums to find ways of providing access to the exhibitions to people with disabilities. Digital museums take into account the need emphasized by the Resource Disability Action Plan and formed by the Council of Museums, Archives and Libraries for efficient ways of using new technologies which allow the access to museum exhibitions to all end-user groups including virtual access to disabled people [75] using AR interfaces designed to operate on off-the shelf computer systems [9].

The cultural artifacts that are exhibited in the physical environment of a museum are usually shown in display cases, where only a limited amount of information about them is available. In virtual museum exhibitions, museum artifacts can be digitized and visualized into a virtual interactive environment. A virtual exhibit can contain information that a physical exhibit in a museum showcase cannot. Thus, museum curators are given the opportunity to offer a more rewarding experience thanks to rich multimedia context information data about the objects, in comparison to artifacts that are locked in a museum glass case with a simple description on a card. In these virtual exhibitions, users may explore exhibits in an interactive and more flexible way. Virtual museum exhibitions provide the experience of allowing virtual visitors to observe and examine an object from all angles. AR exhibitions can also involve physical interfaces (i.e. marker-cards), which are used as the link between real

and virtual worlds. Physical interfaces allow museum visitors to pick up and manipulate virtual cultural objects and examine them within the display system in their hands (i.e. flat screen) [9]. Additionally, a virtual museum gives the user the control of the virtual tour, because it may provide 3D views of a museum and a floor plan. Virtual visitors can orient themselves; know in which room of the virtual exhibition the exhibits are found and to which group of the exhibits an object belongs. The exhibits themselves can convey their meaning, when they are examined in conjunction with the other exhibits of the room and through a narrative that connects the objects and their context and 'brings to life the potential dynamism of objects and their stories' [76].

The communities targeted by virtual museums are the museum curators and the end-users. The second category can be divided into three subcategories: the specialists, the students and the tourists [77,78]. Virtual museum exhibitions can contain a great amount and depth of information, meant to broaden perspectives, satisfy needs and encourage a deeper understanding of virtual visitors of any of the above profiles. They can fulfil the need for "basic and distinguishing information' of simple tourists [79] and they do not need any additional help to deciphering the concepts and the ideas behind museum objects [80, p. 210]. Virtual museums are also capable of providing information to a degree of detail that is sufficient for various kinds of visitors [72] while it may assist the specialised research needs including the comparative study requirements of specialists and students, by providing access not only to one, but to multiple museum collections. Furthermore, creative websites may attract audiences that 'would not normally use libraries or museums' [81] and do not have prior knowledge of or interest in the subject of the museum exhibition [82]. The visitors of virtual museum exhibitions are not passive nor do they lack opportunities to develop their critical skills. A virtual museum can provide visitors with the freedom to explore, to exercise autonomy and to be active participants as they create their own virtual tour and paths. Additionally, the digital tools provided are used as cognitive technologies that help the virtual visitors transcend the limitations of the human mind, such as memory or problem solving limitations [83] and construct their own knowledge. A representative example of the above is the ability provided to virtual museum visitors for creating a personal online exhibition of digitized material, a 'gallery' that corresponds to their interests and they can share it with others [33]. In a virtual museum environment, there are more learning opportunities via educational games than in a physical museum [84,85], as cited by [86]. Most of the virtual museums have been designed by taking into account the constructivist principles of learning through construction and learning through play [87,88] and they involve interaction, experiencing and learning at the same time. In a virtual museum environment, the visitor is not an observer but s/he interacts with the learning objects and s/he constructs her/himself the knowledge. Museum visitors use and interact with the virtual museum environment via a constructive dialogue that provide them with access to thematic information and explanations about the museum objects' context with the level of information and the amount of detail they prefer [89]. Learning is an active process and the end-users are engaged in

hands-on involvement in an engaging experience that enhances the understanding, fosters fruitful learning interactions, awakens and keeps the interest alive and enriches aesthetic sensitivities. Most of the time, virtual visitors do not want to 'learn something' but rather to engage in an 'experience of learning' or 'learning for fun' that can be *'important and enjoyable in its own right'* [90].

5. Problems and implications confronted

New technologies provide new possibilities and impose new restrictions [91]. Despite significant advantages, a virtual museum also presents drawbacks. The forms these take will now be examined. 'VR' (an oxymoron) cannot have the complexity of the real objects. Virtual museum comes from Greek dynaton (gr. $\delta\upsilon\nu\alpha\tau\acute{o}\nu$=possible) and it means "that in potential" (Aristotle, *Analitici primi*) and exists in potential form and not in reality [92]. The problem is that advanced graphic systems that are used for computer reconstructions adopted by virtual museums may sometimes be too realistic. They are based on partial evidence, but they suggest an impression of good knowledge of the past. Sometimes advanced graphic systems present the 'image' as true, giving the sense of misleading accuracy [93,94]. When the reconstructed item has a lot of missing elements then – obviously – scientists must use their imagination or rely on ethno-historical information on how similar cases might have looked like, in order to reconstruct it. However, in these cases, the result will not be an explanation of the past, but a personal and subjective way of seeing it. A good 'image' can give the impression to the viewer that museologists know more than they actually do. Some products of computer reconstructions can be considered as scientifically accurate, because they seem to be accurate. The term "user" is used for virtual museum visitors, because, in order to retrieve information on virtual exhibits, computer skills are required [86]. This means that the computer illiterate are automatically excluded and a lot of visitors encounter difficulties with understanding the use of plug-ins and other applications that need to be downloaded from the Internet and installed in order to retrieve information from sophisticated virtual museum exhibitions.

The idea of the ambiguity between reality and virtuality can be first traced in the Metaphor of the Cave in The Republic of Plato, where people take as real a fact that is an illusion [95]. Prisoners that have been chained and held immobile can only see at a wall in front of them. Behind them, there is a fire and between them and the fire there is a walkway with shadows of moving things and creatures. So, they consider the shadows and the echoes as the only 'reality' and the reflections of objects more important than the objects themselves.

When it comes to building virtual reconstructions, even if there is a degree of accuracy, the one-sided view of the reconstructed site is still wrong. Computer reconstructions that offer only one aspect of the subject they examine and do not provide any alternative reconstructions, contradict the fact that there are many ways to examine the Past. In virtual reconstructions there is only one aspect of the subject that has been reconstructed and no alternative reconstructions have been created. Some

high-quality and sophisticated virtual museums involve collaborations between museologists and computer experts. In such cases, communication problems often arise between those with theoretical knowledge in museology and those with practical knowledge of computers. In most circumstances, the software itself used by virtual museums is not accessible to museologists and computer scientists stand between them and the data. In some cases, it is probable that the Past is both misinterpreted and misrepresented. The visualization results are impressive, thus fulfilling a primary goal, more specifically general public consumption, but without, in turn, serving the museum goals. Virtual museums may provide users with fragmented museum-related information that often bear no obvious information with each other or refer to a useful context. In addition to this, some virtual museums suffer from the lack of clearly identified purposes. Their design must be carried out according to their *raison d'être* and the information provided must be organized in order to construct a narrative [96]. A virtual museum has to define its target community/ies, its aims, its content and how this will be structured and delivered. Throughout all the creation phases of the virtual museum, evaluation studies that involve real users must be undertaken, in order to identify the parts of the program that need further improvement [97].

6. Conclusions

In this paper, the various types of virtual museums in the light of a range of classifications have been discussed. With the use of imaging technology, Web3D, VR, AR, MR, haptics and hand-held devices as PDAs, museums can exploit all possibilities of the new media, analyze and answer in various ways to visitors' needs, enable an intuitive interaction with the displayed content and provide an entertaining and educational experience. The benefits of virtual museums are noteworthy as far as museum curators are concerned and in terms of documentation, conservation, research and exhibition. The virtual museums have the potential to both preserve and disseminate the cultural information in an effectively and at a low-cost through innovative methods and tools. They are an engaging medium with great appeal to a variety of groups of visitors and can promote the 'real sites' by providing information about museum exhibitions and offer an enhanced display of museum artifacts through emerging technologies. Various groups of end-users such as tourists, students and specialists can take advantage of them and satisfy their learning and entertainment needs. The visit of virtual museums can be an enjoyable and productive experience that draws the user into involvement and participation and help the promotion of real museums [98].

The virtual museums enrich the museum experience by allowing an intuitive interaction with the virtual museum artifacts. A comparison between real and virtual museums indicates that there still are important issues for virtual museums to solve. Good collaboration must be ensured between cultural heritage specialists (museum curators, historians, archaeologists, etc.) and information science specialists to achieve optimal results and in order to avoid dependence on market-produced software and to promote open-source software that may be produced with the aid of cultural heritage specialists. Virtual museums cannot and do not intend to replace the walled museums. They can be characterised as 'digital reflections' of physical museums that do not exist *per se*, but act complementarily to become an extension of physical museums exhibition halls and the ubiquitous vehicle of the ideas, concepts and 'messages' of the real museum. Their primary aim is (or should be) to investigate and propose models for the exploration of the real purpose and conceptual orientation of a museum.

References

[1] R. Silverstone, The medium is the museum, in: R. Miles, L. Zavala (Eds.), Towards the Museum of the Future, Routledge, London/New York, 1994, pp. 161–176.

[2] J. Jones, M. Christal, The Future of Virtual Museums: On-Line, Immersive, 3D Environments, Created Realities Group, 2002.

[3] G. Scali, M. Segbert, B. Morganti, Multimedia applications for innovation in cultural heritage, in: Proceedings of 68th IFLA Council and General Conference, August 2002, Glasgow, U.K., 2002.

[4] ORION Report on Scientific/Technological Trends and Platforms, available at: http://www.orion-net.org.

[5] D. Pletinckx, D. Callebaut, A. Killebrew, N. Silberman, Virtual-reality heritage presentation at Ename, IEEE Multimedia 7 (2) (2000) 45–48.

[6] M. Roussou, Immersive interactive virtual reality in the museum, in: Proceedings of TiLE, June 2001, London, U.K, 2001.

[7] R. Wolciechowski, K. Walczak, M. White, W. Cellary, Building Virtual and Augmented Reality Museum Exhibitions, in: Proceedings of the 9th Int. Conference on 3D Web Technology, California, USA, April 2004, ACM SIGGRAPH, 2004, pp. 135–144.

[8] A. Brogni, C.A. Avizzano, C. Evangelista, M. Bergamasco, Technological approach for cultural heritage: augmented reality, in: Proceedings of the RO-MAN 99 Conference, Pisa, Italy, September 1999, 1999, pp. 206–212.

[9] F. Liarokapis, S. Sylaiou, A. Basu, N. Mourkoussis, M. White, P.F. Lister, An interactive visualisation interface for virtual museums, in: K. Cain, Y. Chrysanthou, F. Niccolucci, N. Silberman (Eds.), Proceedings of the VAST 2004 Conference, Belgium, EPOCH Publication, Belgium, 2004, pp. 47–56.

[10] F. Liarokapis, M. White, Augmented reality techniques for museum environments, The Mediterranean Journal of Computers and Networks 1 (2) (2005) 90–96.

[11] M. White, N. Mourkoussis, J. Darcy, P. Petridis, F. Liarokapis, P.F. Lister, K. Walczak, R. Wolciechowski, W. Cellary, J. Chmielewski, M. Stawniak, W. Wiza, M. Patel, J. Stevenson, J. Manley, F. Giorgini, P. Sayd, F. Gaspard, ARCO—An Architecture for digitization, management and presentation of virtual exhibitions, in: Proceedings of the CGI'2004 Conference, Hersonissos, Crete, June 2004, Los Alamitos, California: IEEE Computer Society, 2004, pp. 622–625.

[12] P.A.S. Sinclair, K. Martinez, D.E. Millard, M.J. Weal, Augmented reality as an interface to adaptive hypermedia systems. New review of hypermedia and multimedia, Special Issue on Hypermedia beyond the Desktop 9 (1) (2003) 117–136.

[13] P. Patias, Y. Chrysanthou, S. Sylaiou, H. Georgiadis, S. Stylianidis, The development of an e-museum for contemporary arts, in: Proceedings of the VSMM Conference on Virtual Systems and Multimedia dedicated to Cultural Heritage 2008, 20–25 October, Nicosia, Cyprus, 2008.

[14] S.M. Pearce, Thinking about things. approaches to the study of artifacts, Museum Journal (1986) 198–201.

[15] W.E. Washburn, Collecting information, not objects, Museum News 62 (3) (1984) 5–15.

[16] G. McDonald, S. Alsford, The museum as information utility, Museum Management and Curatorship 10 (1991) 305–311.

[17] S. Alsford, Museums as hypermedia: Interacting on a museum-wide scale, in: D. Bearman (Ed.), Proceedings of the ICHIM '91 Conference, Pittsburgh, Pennsylvania, USA, October 1991, 1991, pp. 7–16.

[18] Information today, December 2005, pp. 31–34, available at: http://www.infotoday.com.

[19] A. Malraux, La Musée immaginaire, Gallimard, Paris, 1996 [orig. 1947].

[20] Encyclopaedia Britannica online, available at: http://www.britannica.com/eb/article-9000232.

[21] W. Schweibenz, The virtual museum: new perspectives for museums to present objects and information using the Internet as a knowledge base and communication system, in: H. Zimmermann, H. Schramm (Eds.), Proceedings of the 6th ISI Conference, Prague, November 1998, Konstanz, UKV, 1991, pp. 185–200.

[22] 3D Van Gogh, Museum Virtual Tour', available at: http://www3.vangoghmuseum.nl/vgm/index.jsp?page=49335&lang=en.

[23] ARCO, ARCO (Augmented Representation of Cultural Objects) Consortium. Available at: http://www.arco-web.org.

[24] ICOM News, no. 3, 2004, available at: http://icom.museum/pdf/E_news2004/p3_2004-3.pdf.

[25] L. Teather, A museum is a museum. Or is it?: Exploring museology and the web, in: D. Bearman, J. Trant (Eds.), Proceedings of the Conference Museums and the Web, 1998, Pittsburgh, 1998.

[26] M. McDonald, The Museum and the Web: Three Case Studies, available at : http://xroads.virginia.edu/~MA05/macdonald/museums/method.html.

[27] M. Bergamasco, A. Frisoli, F. Barbagli, Haptics Technologies and Cultural Heritage Applications, in: S. Kawada (Ed.), IEEE Proceedings of the CA Conference 2002, Geneva, Switzerland, June 2002, IEEE Computer Society Press, 2002, pp. 25–32.

[28] S. Worden, Thinking critically about virtual museums, in: D. Bearman, J. Trant (Eds.), Proceedings of the Conference Museums and the Web, 1997, Pittsburgh, 1997, pp. 93–109.

[29] L.T.W. Hin, R. Subramaniam, A.K. Aggarwal, Virtual Science Centers: A new genre of learning in web-based promotion of science education, in: Proceedings of the 36th Annual HICSS'03 Conference, IEEE Computer Society, 2003, pp. 156–165.

[30] O. Georgoula, P. Patias, Visualization tools using FlashPix image format, in: A. Gruen, S. Murai, J. Niederoest, F. Remondino (Eds.), Proceedings of the International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences, vol. XXXIV, PART 5/W10, February 2003, 2003.

[31] San Francisco Fine Arts Museums, http://www.thinker.org/.

[32] N. Talagala, S. Asami, D. Patterson, B. Futernick, D. Hart, The Berkeley-San Francisco Fine Arts image database, in: B. Kobler, P.C. Hariharan (Eds.), Proceedings of the 15th IEEE Symposium on Mass Storage Systems, Maryland, USA, March 1998, 1998, available at: http://romulus.gsfc.nasa.gov/msst/conf1998/B5_06/TALAGA.pdf.

[33] Metropolitan Museum of Art in New York, available at: http://www.metmuseum.org/.

[34] D. Marshak, J. Paul Getty Museum Re-Architects Technology to Enhance Visitors Experience, available at: http://www.sun.com/products-n-solutions/edu/casestudy/pdf/getty_museum.pdf.

[35] Virtual Display Case, Making Museum Image Assets Safely Visible, 3rd ed., available at: http://www.chin.gc.ca/English/Intellectual_Property/Virtual_Display_Case/.

[36] A.N. Skodras, C.A. Christopoulos, T. Ebrahimi, The JPEG2000 still image compression standard, IEEE Signal Processing Magazine 18 (5) (2001) 36–58.

[37] S. Sylaiou, P. Patias, O. Georgoula, L. Sechidis, Digital image formats suitable for museum publications, in: Proceedings of the 2nd International Museology Conference in Technology for the Cultural Heritage, Lesvos, Greece, June 2004, 2004.

[38] Charles Olson's Melville Project digital library, available at: http://charlesolson.uconn.edu/Works_in_the_Collection/Melville_Project/index.htm.

[39] National Archives of Japan, available at http://jpimg.digital.archives.go.jp/kouseisai/word/abc.html.

[40] Digital Collections of the University of South Carolina Libraries, available at: http://www.sc.edu/library/digital/.

[41] Web3D consortium, available at: http://www.web3d.org (accessed at 6/08/2007).

[42] S. Goodall, P.H. Lewis, K. Martinez, P. Sinclair, M. Addis, C. Lahanier, J. Stevenson, Knowledge-Based Exploration of Multimedia Museum Collections, in: Proceedings of the EWIMT Conference, November 2004, London, U.K., 2004.

[43] VRML, The Annotated VRML 97 Reference, available at: http://accad.osu.edu/~pgerstma/class/vnv/resources/info/AnnotatedVrmlRef/ch1.htm.

[44] Benaki Museum, available at: http://www.benaki.gr.

[45] Rembrandt House Museum, available at: http://www.rembrandthuis.nl/cms_pages/index_main.html.

[46] COLLADA – Digital Asset Schema Release 1.5.0, http://www.khronos.org/files/collada_spec_1_5.pdf.

[47] OpenSceneGraph, 2009. Available at: http://www.openscenegraph.org/projects/osg.

[48] QuakeDev, 2009. Available at: http://www.quakedev.com/.

[49] Second Life, 2009. Available at: http://secondlife.com/.

[50] J. Looser, R. Grasset, H. Seichter, M. Billinghurst, 2006. OSGART – A pragmatic approach to MR, In ISMAR 2006.

[51] L. Calori, C. Camporesi, M. Forte, A. Guidazzoli, S. Pescarin, Openheritage: integrated approach to web 3D publication of virtual landscape, in: Proceedings of the ISPRS Working Group V/4 Workshop, 3D-ARCH 2005: Virtual Reconstruction and Visualization of Complex Architectures, Mestre-Venice, Italy, 22–24 August, 2005.

[52] M. Heim, The Metaphysics of Virtual Reality, Oxford University Press, Oxford, 1993.

[53] Foundation of the Hellenic World, available at: http://www.ime.gr.

[54] Cortona, VRML Client – Web3D Products, available at: http://www.parallelgraphics.com/products/cortona/.

[55] Y.M. Kwon, J.E. Hwang, T.S. Lee, M.J. Lee, J.K. Suhl, S.W. Ryul, Toward the synchronized experiences between real and virtual museum, in: Proceedings of Conference of APAN, January 2003, Japan, 2003.

[56] B.B. Bederson, Audio augmented reality: a prototype automated tour guide, in: R. Mack, J. Miller, I. Katz, L. Marks (Eds.), Proceedings of the ACM Conference on CHI'95, Denver Colorado, USA, May 1995, ACM Press, New York, 2003.

[57] K. Mase, R. Kadobayashi, R. Nakatsu, Meta-Museum: A Supportive Augmented-Reality Environment for Knowledge Sharing, in: Proceedings of the Conference VSMM '96, Japan, September 1996, IEEE Computer Society Press, 1996, pp. 107–110.

[58] P. Milgram, F. Kishino, A Taxonomy of Mixed Reality Visual Displays, IEICE Transactions on Information and Systems, Special issue on Networked Reality, E77-D (12), (1994) 1321–1329.

[59] C.E. Hughes, C.B. Stapleton, D.E. Hughes, E. Smith, Mixed reality in education, entertainment and training: An interdisciplinary approach, IEEE Computer Graphics and Applications 26 (6) (2005) 24–30.

[60] T. Hall, L. Ciolfi, M. Fraser, S. Benford, J. Bowers, C. Greenhalgh, S. Hellstrom, S. Izadi, H. Schnadelbach, The visitor as virtual archaeologist: using mixed reality technology to enhance education and social interaction in the museum, in: S. Spencer (Ed.), Proceedings of the VAST 2001 Conference, Greece, November 2001, ACM Press, New York, 2001.

[61] B. Baird, Using haptics and sound in a virtual gallery, in: M.A. Srinivasan (Ed.), Proceedings of the Fifth Annual PHANToM Users Group Workshop, October 2000, Aspen, Colorado, USA, 2000.

[62] S. Brewster, The impact of haptic 'Touching' technology on cultural applications, in: J. Hemsley (Ed.), Proceedings of the EVA 2001 Conference, Glasgow, UK, July 2001, Academic Press, Vasari UK, 2001, pp. 1–14, s28.

[63] M. McLaughlin, G. Sukhatme, J. Hespanha, C. Sharabi, A. Ortega, G. Medioni, The haptic museum, in: V. Cappellini, J. Hemsley (Eds.), Proceedings of the EVA 2000 Conference, Florence, Italy, March 2000, Pitagora Editrice Bologna, 2000.

[64] M. Bergamasco, Le musée de formes purés, in: M. Bergamasco (Ed.), Proceedings of the EVA 2000 Conference, Proceedings of the 8th IEEE International Workshop on Robot and Human Interaction, RoMan '99, Pisa, Italy, September 1999, IEEE Computer Society, 1999, pp. 27–29.

[65] A. Galani, M. Chalmers, B. Brown, I. McColl, C. Randell, A. Steed, Developing a mixed reality co-visiting experience for local and remote museum companions, in: J. Jacko, C. Stephanidis (Eds.), Proceedings of the 10th Conference of HCI, Crete, Greece, June 2003, Lawrence Erlbaum Associates, 2003, pp. 1143–1147.

[66] San Francisco Museum of Modern Art, 2001, 'Points of Departure', available at: http://www.sfmoma.org/press/pressroom.asp?arch=y&id=117&do=events.

[67] S. Sauer, S. Göbel, Focus your young visitors: kids innovation – fundamental changes in digital edutainment, in: M. Bergamasco (Ed.), Proceedings of the Conference Museums and the Web 2003, Charlotte, USA, Toronto, 2003, pp. 131–141.

[68] Development of the Museum Definition according to ICOM Statutes (1946–2001), available at: http://icom.museum/hist_def_eng.html.

[69] R.J. Loomis, S.M. Elias, M. Wells, 2003. Website availability and visitor motivation: An evaluation study for the Colorado Digitization Project. Unpublished Report. Fort Collins, CO: Colorado State University, available at: http://www.cdpheritage.org/resource/reports/loomis_report.pdf.

[70] S. Sylaiou, F. Liarokapis, L. Sechidis, P. Patias, O. Georgoula, Virtual museums, the first results of a survey on methods and tools, in: Proceedings of the CIPA and the ISPRS Conference, Torino, Italy, 2005, pp. 1138–1143.

[71] Museums in the USA, available at: http://www.museumca.org/usa/alpha.html.

[72] UN Convention on the Rights of Persons with Disabilities, http://www.ohchr.org/english/law/disabilities-convention.htm.

[73] Americans with Disabilities Act of 1990 (ADA), http://www.usdoj.gov/crt/ada/adahom1.htm.

[74] Disability Discrimination Act 1995, available at: http://www.disability.gov.uk/dda/.

[75] Resource Disability Action Plan, available at: http://www.mla.gov.uk/documents/dap.pdf.

[76] Research on 'Quality' in Online Experiences for Museum Users, available at: http://www.chin.gc.ca/English/Digital_Content/Research_Quality/about_vmc.html.

[77] S. Filippini-Fantoni, Museums with a personal touch, in: J. Hemsley, V. Cappellini, G. Stanke (Eds.), Proceedings of EVA 2003 Conference, University College London, July 2003, Vasari, UK, s25, 2003, pp. 1–10.

[78] J.P. Bowen, S. Filippini-Fantoni, Personalization and the web from a museum perspective, in: D. Bearman, J. Trant (Eds.), Proceedings of the Conference Museums and the Web 2004, Arlington, Virginia, USA, April 2004, 2004, pp. 63–78.

[79] F. Paternò, C. Mancini, Effective levels of adaptation to different types of users in interactive museum systems, Journal of the American Society for Information Science 51 (1) (2000) 5–13.

[80] E. Hooper-Greenhill, Museums and the Shaping of Knowledge, Routledge, London, 1992.

[81] M. McDonald, The Museum and The Web, Comparing the Virtual and the Physical Visits, available at: http://xroads.virginia.edu/~ma05/macdonald/museums/virtual.pdf.

[82] M. Economou, The evaluation of museum multimedia applications: lessons from research, Museum Management and Curatorship 17 (2) (1998) 173–187.

[83] R.D. Pea, Beyond amplification: Using the computer to reorganize mental functioning, Educational Psychologist 20 (4) (1985) 167–182.

[84] J. Davallon, Une écriture éphémère : l'exposition face au multimedia, Degrés (92–93) (1998) 25–26.

[85] M. Mokre, New technologies and established institutions, in: How Museum Present Themselves in the World Wide Web, Technisches Museum Wien, Austria, 1998.

[86] R. Bernier, The uses of virtual museums: the French viewpoint, in: D. Bearman, J. Trant (Eds.), Proceedings of the Conference Museums and the Web 2002, Boston, USA, April 2002, 2002, available at: http://www.archimuse.com/mw2002/papers/bernier/bernier.html.

[87] G. Hein, Constructivist Learning Theory, in: Proceedings of Developing Museum Exhibitions for Lifelong Learning Conference, ICOM/CECA, Israel, 1991, 1991, available at: http://www.exploratorium.edu/IFI/resources/constructivistlearning.html.

[88] J.H. Falk, L.D. Dierking, Learning from Museums: Visitor Experiences and the Making of Meaning, Altamira Press, Walnut Creek, CA, 2000.

[89] F. Liarokapis, S. Sylaiou, D. Mountain, Personalizing Virtual and Augmented Reality for Cultural Heritage Indoor and Outdoor Experiences, in: Proceedings of the 9th International Symposium on Virtual Reality, Archaeology and Cultural Heritage (VAST 08), Eurographics, Braga, Portugal, 2-5 Dec, 55–62, (2008), 2008.

[90] J. Packer, Learning for fun: The unique contribution of educational leisure experiences, Curator: The Museum Journal 49 (3) (2006) 329–344.

[91] S. Sylaiou, P. Patias, Virtual reconstructions in archaeology and some issues for consideration, IME*ros*, Journal for Culture and Technology (4) (2004) 180–191.

[92] M. Forte, About virtual archaeology: disorders, cognitive interactions and virtuality, in: J. Barcelò, M. Forte, D.H. Sanders (Eds.), Virtual Reality in Archaeology, BAR International Series 843, Archaeopress, Oxford, 2000, pp. 247–259.

[93] P. Miller, J. Richards, The good, the bad, and the downright misleading: archaeological adoption of computer visualization, in: J. Hugget, N. Ryan (Eds.), Proceedings of the CAA 1995 Conference, Oxford, U.K., Tempus Reparatum, BAR International Series 600, 1995, pp. 19–22.

[94] N.S. Ryan, Computer based visualisation of the past: technical 'realism' and historical credibility, Imaging the Past, British Museum Occasional Paper 114 (1996) 95–108.

[95] Plato: Republic. Barnes & Noble Books, 2004.

[96] J. Bonnett, New technologies, new formalisms for historians: The 3D virtual buildings, Literary and Linguistic Computing 19 (3) (2004) 273–287.

[97] S. Sylaiou, M. Economou, A. Karoulis, L.M. White, The evaluation of ARCO: a lesson in curatorial competence and intuition with new technology ACM Computers in Entertainment, 6(2), ACM Press, New York, 2008.

[98] R. Jackson, M. Bazley, D. Patten, M. King, Using the web to change the relation between a museum and its users, in: D. Bearman, J. Trant (Eds.), Proceedings of the Conference Museums and the Web 1998, Toronto, Canada, April 1998, Archives and Museum Informatics, Pittsburgh, 1998.